

**SUBSTITUTE SPECIFICATION AND ABSTRACT FOR  
U.S. SERIAL NO. 10/727,677**

**MARKED-UP COPY**

**APPARATUS AND METHOD FOR MONITORING BODY COMPOSITION  
BY MEASURING BODY DIELECTRIC CONSTANT AND BODY  
IMPEDANCE BASED ON THE METHOD OF FREQUENCY DIGITAL  
SAMPLING**



The present application claims priority of European patent application Serial No. 02028205.9, filed December 14, 2002, the content of which is hereby incorporated by reference in its entirety.

**FIELD OF THE INVENTION**

The present invention relates to measurement devices in general, and more particularly to a body composition monitor ~~apparatus~~ by measuring which measure dielectric constant of body endermie-tissues under the skin and body impedance based on the method of frequency digital sampling.

**BACKGROUND OF THE INVENTION**

Body composition refers to the total contents consisting of every tissue and organ of a human's body, its total weight is namely body weight, which is composed of two parts: fat and non-fat content. The former mass is called body fat mass, the ratio between it and body mass is called percent body fat (Fat %) in human body. The latter includes the weight of water, viscera, bones, muscle, mineral salts and so on, and is also called lean body mass or fat free mass, among which water content accounts for most of the mass. 70% fat content is mainly distributed in and below the region of the waist.

Body composition indicates the rates of ~~body tissue structure such as lean body mass (LBM) and body fat~~. Different tissue body structure contents result in different body functions and activity, and in order to maintain the body's normal functions, it is required that all contents adjust to one another at certain rates. Once the maladjusted rates destroy the normal physiological functions and activity, the normal growth and health of the body will be affected. Body composition can also indicate physical attributes, body shape characteristic and body stature, and fat content can indicate body fitness. So body composition is significant to make the fitness standard and body shape assessment and so on.

There are already some methods ~~and fruits~~ for measuring body fat content alone, such as isotope dilution method, underwater weighing method, height and weight empirical algorithms, ultrasound measurement, infrared measurement and so on. All these methods have the shortcomings of complicated equipment and inconvenient operation.

There are three indices for measuring body water content: total body water (TBW), intracellular water (ICW) and extracellular water (ECW). TBW equals the sum of ICW and ECW, and these three indices are significant to assess the physical attributes and the balance status of intracellular and extracellular liquid. There are also corresponding methods for measuring body water. The method often used is druggery dilution method. For example, to take certain doses of antibilin or D<sub>2</sub>O, after these medical substances disperse uniformly to global body, to extract some sample of blood and urine for testing. Also there is a method called multiple-factor isotope dilution, which can measure multiple body contents including water content from microcosmic aspect. None of these methods presented above can meet the demand of

fast and integrated monitoring of body weight, fat and water content. Especially some methods of medical substance dilution, can only be done in hospitals, have long time period, cost much and can not be done as often as needed.

The method of bioelectrical impedance analysis (BIA) is considered to be the simplest method for measuring human body composition (such as fat content). This method is based upon the principle that body tissue conductivity of bio electricity in different ~~regions~~areas of the body stimulated by outside electricity is different. For example, the conductivity of muscle is high and then the impedance is small because of its high rate of water content, while the conductivity of fat tissue, bone tissue and lung tissue filled with air is very low and the impedance is relatively great. So body composition can be estimated according to tissue's impedance. Up to now, though those open patents on measuring body composition based on bioelectrical impedance analysis (BIA) adopt different circuits, arithmetic, apparatus structures and different output methods, they have three common characteristic in nature, the first is to obtain bioelectric impedance by measuring voltage or voltage difference then transforming to digital value through A/D, the second is to use at least more than three electrodes (groups), among which two electrodes is certain to apply high frequency small current to human body in order to stimulate bio electricity and the other two electrodes collect stimulated voltage signal indicating bioelectrical impedance, if unite two of four electrodes to be used as reference electrodes, then there are 3 electrodes, the third is that the different frequency signals applied to human body must be signals with determined frequencies. As disclosed in U.S. Pat. No.6, 151, 523, bioelectrical impedance can be measured by placing electrodes at a person's toes and heels, and by inputting the weight and height of the subject, percent body fat can also be estimated. But the shortcoming of this patent is more electrodes and no body water measuring. European Patent No.EP1147740A1 shown a living body variable measuring device. The measuring method of the patent is feeding a high frequency current to body and then measuring the voltage or voltage difference for estimating bioelectrical impedance. One of mode of signal transmission of this patent is that the weight scale-like body and box-like display device are provided with wireless communication means for signal communication between weight scale-like body and box-like display device, but no technical detail is indicated. There are 2 shortcomings in this patent. Firstly, there are 4 electrodes in the device, 2 electrodes for feeding a high frequency current to body and 2 electrodes for measuring the voltage, so as to forming feeding current circuit and voltage measuring circuit respectively, which are complicated. Secondly, the voltage measuring circuit needs an A/D converter for converting analog signals from the voltage measuring circuit to digital signals. European patent No.EP1080686A1 shown another bioelectrical impedance measuring method and body composition measuring apparatus, in which a first, second and third bioelectrical impedance values are determined by a measurement using the alternating current having a first, second and third frequency respectively. Then, a vector impedance locus is derived from only the derived first, second and third bioelectrical impedance values to determine the bioelectrical impedance values at 0 frequency and at infinite frequency. The shortcomings of this patent are also complicated measuring circuit and the A/D converter for converting analog signals from the voltage measuring circuit to digital signals. The Patent No.WO02/080770A1 shown a method for measuring of edema. By the method an electromagnetic probe (20-500MHZ) is placed on the skin, and the capacitance of the probe is proportional to the dielectric constant of the skin and subcutaneous fat, which is proportional to the water content of the skin. The shortcomings of this patent are that for the measurement the probe is secured on the

skin by an attachment, such as strap-like attachment, which is discommodious. The Patent No. WO01/036952A1 shown a method for measuring skin surface hydration and device for applying the method, in which method a electromagnetic probe is placed on the skin for measuring the capacitance of the skin, characterized in that a wave signal is transmitted into the probe, the capacitance of the probe is measured by comparing the phases of the direct and reflected wave. The shortcomings of this patent are that the structure of the electromagnetic probe is coaxial and complicated. The shortcomings of the above methods are: first, the methods have limitation if body fat and water content are determined based on bioelectrical impedance alone, second, because of the great diversity of human bodies, if only one or multiple determined frequencies are applied to human body, the results can not indicate body status accurately, third, there are large error in those low-cost apparatus when use voltage measurement to determine body impedance.

### **OBJECTS OF THE INVENTION**

The present invention aims to solve those questions above, the object is to provide a method for measuring dielectric constant of body ~~endemie~~-tissues under the skin by using capacitance sensor contacting body skin and based on the method of frequency digital sampling.

The present invention also aims at providing a method according to which, human body is connected with oscillator circuit as a two end impedance element, then generates unfixed frequencies related to body impedance, and by sampling frequency, the digital signal, the body impedance is determined.

The present invention also aims to provide a method of determining body composition by jointly using measurement of two parameters: dielectric constant of body ~~endemie~~-tissues under the skin and body impedance.

The present invention also aims to provide a body composition monitor for measuring body dielectric constant and body impedance based on the method of frequency digital sampling, and the monitor is used to monitor body composition in everyday life.

### **SUMMARY OF THE INVENTION**

The present invention includes two kinds of measuring modes and corresponding apparatus for composition monitoring. The first mode is to assemble the measuring unit and display unit in an integrative apparatus. The apparatus includes feet-on electrode plates and capacitance grid sensor, both of which are attached to the platform of weighing scale, body impedance and water measuring circuits, weighing sensor, weighing signal process circuit, microprocessor system, display, keyboard, and so on. Before measurement, the subject's gender, height and age are input by keyboard. The measuring results including body weight, fat content, water content and so on are shown on the display. The second mode is measuring unit and display unit are separated as measuring apparatus and display apparatus physically. The measuring apparatus includes feet-on electrode plates and capacitance grid sensor, both of which are attached to the platform of weighing scale, weighing sensor, infrared signal emitting and receiving circuit, microprocessor system, body impedance and water test circuit, weighing signal process circuit and so on. The display apparatus consists of infrared signal emitting and receiving circuit, microprocessor system, display, keyboard and so on. Before measurement, the subject's gender, height and age are input by keyboard of display apparatus. Measuring apparatus emits the results of weight, fat content, water content by infrared

signal transmitting circuit to display apparatus hand-held or hung up on wall, and the results are shown on display.

Because the dielectric constant of body endemie-tissues under the skin is related directly to the fat content and water content of body tissues, the present invention regards the dielectric constant of body endemie-tissues under the skin as a measuring parameter for evaluating body composition. The present invention's method and principle for measuring dielectric constant of body endemie-tissues under the skin is: when a testee stands with barefoot on the measuring platform, his soles of two feet contact two capacitance grid sensors, and the oscillator circuit connected with capacitance grid sensors generates oscillating frequency signals related to dielectric constant of body endemie-tissues under the skin, the signals are sampled and then the dielectric constant of body endemie-tissues under the skin can be obtained.

Because body impedance is related directly to the fat content and water content of body tissues, the present invention regards the body impedance as a measuring parameter for evaluating body composition. The present invention's method and principle for measuring body impedance is: when a testee stands with barefoot on the measuring platform, his two feet contact two (groups of) electrode plates mounted on the platform simultaneously and respectively. At this time human body is connected with oscillator circuit as a two ends impedance element and a loop is formed at and below human's waist region. The oscillating frequency of the oscillator circuit is related to the impedance of human body. By changing parameters of other elements of oscillator circuit, several different frequency signals are obtained related to body impedance, then the body impedances corresponding to several different frequencies are determined.

The method and principle of the present invention to determine body composition by jointly using measurement of the two kinds of measuring parameters, dielectric constant of body endemie-tissues under the skin and body impedance, is to introduce to math models the dielectric constant of body endemie-tissues under the skin, the body impedance, body weight obtained from weighing sensor and circuit, and the input data by keyboard, to calculate by microprocessor, and to display body weight, body fat content, total body water (TBW) and the ratio between intracellular water and TBW (ICW/TBW) by display.

The math models for calculating these data are as follows:

$$\text{Fat} = \frac{a_1 H + a_2 W + a_3 R_{m1} + a_4 R_{m2} + a_5 R_{m3} + a_6 Y + a_0}{c e^{-(b_1 H + b_2 W)}}$$

$$\text{Fat}(\%) = \frac{\text{Fat}}{W}$$

$$\text{TBW} = \frac{\text{Fat} + K_1 \varepsilon_r}{K_2 \varepsilon_r} + K_3$$

where W is body weight (Kg), Rm1, Rm2, Rm3 are body impedance corresponding respectively to three kinds of undetermined frequencies.  $\varepsilon_r$  is the dielectric constant of body endemie-tissues under the skin; Fat is body fat value(kg); Fat(%) is percent body fat; H is body height (cm); Y is a subject's age,  $a_0, a_1, a_2,$

$a_3, a_4, a_5, a_6, b_1, b_2, c, K_1, K_2, K_3, K_4$  are all coefficients, whose values are related to gender. Among these parameters,  $W, R_{m1}, R_{m2}, R_{m3}, \epsilon, r$  are determined by measurement,  $H, Y$  and gender are input by keyboard.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig1A is a schematic view showing the mode of assembling the function units of measuring and displaying body composition in an integrative apparatus.

Fig1B is a schematic view showing the mode of separating the function units of measuring and displaying body composition to measuring apparatus and display apparatus physically.

Fig2A shows an embodiment example of measuring platform configuration of the integrative apparatus based on the mode shown in Fig1A.

Fig2B shows an alternative embodiment example of measuring platform configuration of the integrative apparatus based on the method shown in Fig1A.

Fig3A shows the system configuration based on the integrative apparatus shown in Fig2A.

Fig3B shows the system configuration based on the integrative apparatus shown in Fig2B.

Fig4A shows an embodiment example of measuring platform configuration of measuring apparatus based on the mode shown in Fig1B.

Fig4B shows an alternative embodiment example of measuring platform configuration of measuring apparatus based on the mode shown in Fig1B.

Fig5A is a schematic view showing the system configuration based on the measuring apparatus shown in Fig4A.

Fig5B is a schematic view showing the system configuration based on the measuring apparatus shown in Fig4B.

Fig6 is a schematic view showing the platform configuration of display apparatus based on the measuring mode shown in Fig1B.

Fig7A is a schematic view showing the first kind of electrode configuration of capacitance grid sensor measuring the dielectric constant of body ~~endemie~~-tissues under the skin.

Fig7B is a schematic view showing the second kind of electrode configuration of capacitance grid sensor measuring the dielectric constant of body ~~endemie~~-tissues under the skin.

Fig7C is a schematic view showing the ~~third~~first kind of electrode configuration of capacitance grid sensor measuring the dielectric constant of body ~~endemie~~-tissues under the skin.

Fig7D is a schematic view showing the ~~fourth~~second kind of electrode configuration of capacitance grid sensor measuring the dielectric constant of body ~~endemie~~-tissues under the skin.

Fig8 is a schematic view showing the measuring mode of measuring the dielectric constant of body ~~endemie~~-tissues under the skin and body impedance by applying undetermined frequencies through sole.

Fig9 is a schematic diagram showing the circuit system structure of measuring the dielectric constant of body ~~endemie~~-tissues under the skin and body impedance

by using undetermined frequencies.

Fig10 is a schematic diagram showing the positive feedback RC oscillator circuit for measuring the dielectric constant of body ~~endemie~~-tissues under the skin in the positive feedback RC oscillator circuit for measuring the dielectric constant of body ~~endemie~~-tissues under the skin and body impedance.

Fig11 is a schematic view showing the circuit for measuring the body impedance in the positive feedback RC oscillator circuit for measuring dielectric constant of body ~~endemie~~-tissues under the skin and body impedance.

Fig12 is an alternative schematic view showing the circuit for measuring the body impedance in the positive feedback RC oscillator circuit for measuring dielectric constant of body ~~endemie~~-tissues under the skin and body impedance.

Fig13 is a schematic diagram showing circuit structure based on the display apparatus shown in Fig6.

Fig14 is a schematic diagram showing the configuration of infrared signal transmitting circuit in measuring apparatus based on the measuring mode shown in Fig 1B.

Fig15 is a schematic diagram showing the configuration of infrared signal transmitting circuit in display apparatus based on the measuring mode shown in Fig 1B.

## **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

Referring now to Fig1A, The first measuring mode is to assemble the measuring function unit and display function unit into a integrative apparatus. A testee stands with barefoot on the platform 1 of the integrative apparatus attaching feet-on electrode plates and capacitance grid sensor. The testee's data are input by keyboard 2 of the integrative apparatus. The determined results by measurement including weight, fat content and water content are shown on display 3.

Referring now to Fig1B, The second mode is that the measuring function unit and display function unit are separated as measuring apparatus and display apparatus physically. There are microprocessors in both the measuring apparatus and display apparatus, and data are transmitted between the two apparatus by the transmitting manner of infrared 7. A testee stands with barefoot on the platform 4 of measuring apparatus attaching foot-on electrode plates and capacitance grid sensor. The testee's data are input by display apparatus 6 held in hand by the testee. Measuring apparatus emits determined data including body weight, body fat ratio and body water ratio in infrared 7 transition manner through window 5 to display apparatus and then these data are shown here.

There are two embodiment examples of the measuring platform configuration of the integrative apparatus in the present invention.

Referring now to Fig2A, it shows a kind of measuring platform configuration of integrative apparatus based upon the measuring mode shown in Fig1A. The platform 1 is positioned on scale sensor. The surface of the platform 1 is insulative and, there are two electrodes 8, 9 on the platform, which have enough area to be contacted by human's sole and are made of conductive materials. There is no conduction between electrodes 8 and 9, between electrodes 8, 9 and platform 1. Also on the platform 1 there is at least more than one capacitance grid sensors 10, 11, which are used to measure the dielectric constant body ~~endemie~~-tissues under the skin and can be contacted by human's soles. Keyboard 2 and display 3 are located on platform 1.

Referring now to Fig2B, it shows another kind of measuring platform configuration of integrative apparatus based upon the measuring mode shown in Fig1A. The

platform 101 is positioned on scale sensor. The surface of the platform 101 is insulative, and there are two electrodes 12, 13 comprising electrode plates connected by conducting wires on the platform 101. There is no conduction between electrodes 12 and 13, between electrodes 12,13 and platform 101. Also on the platform there are at least one or more capacitance grid sensors 10, 11, which can be contacted by human's soles. Keyboard 2 and display 3 are located on platform 101.

Referring now to Fig3A, it shows the system configuration of integrative apparatus shown in Fig2A. Electrode plates 8, 9 and capacitance grid sensors 10, 11 are connected with the interfaces of positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance, and positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance is connected with two interfaces of microprocessor MCU system 15 of the integrative apparatus. One of the two interfaces is a signal collection interface of MCU system 15 of the integrative apparatus, the other is a control interface of MCU system 15 of the integrative apparatus used to send switch instruction to positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance in order to switch undetermined multiple frequencies and measuring signals of the dielectric constant of body endermie-tissues under the skin. The signal wires of weighing sensor 19 are connected with weighing signal process circuit 18, in which the signal from weighing sensor 19 is converted into frequency signal, and the processed frequency signal is applied to one interface of the MCU system 15 of the integrative apparatus through weighing signal processing circuit 18. Display 16 is connected with the output of MCU system 15 of the integrative apparatus and is used to show the input data and the measuring result. Keyboard 17 is connected with the I/O interface of MCU system 15 of the integrative apparatus and is used to input data to MCU system 15 of the integrative apparatus.

Referring now to Fig3B, it shows the system configuration of integrative apparatus shown in Fig2B. The two groups of electrode 12, 13 composed of electrode plates connected with one another by wires and being able to contact human's soles, and capacitance grid sensor 10, 11 are connected with the interfaces of positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance, and positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance is connected with two interfaces of MCU system 15 of the integrative apparatus. One of the interfaces is the signal collection interface of MCU 15 system of the integrative apparatus and the other is a control interface of the MCU system 15 of the integrative apparatus used to send switch instruction to positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance in order to switch undetermined multiple frequencies and the measuring signal of body dielectric constant of endermie-tissues under the skin. The signal wires of weighing sensor 19 are connected with weighing signal process circuit 18, in which the signal from weighing sensor 10 is converted into frequency signal, and the processed frequency signal is applied to one interface of MCU system 15 of the integrative apparatus through weighing signal processing circuit 18. Display 16 is connected with the output of MCU system 15 of the integrative apparatus and is used to show the input data and the measuring results. Keyboard 17 is connected with the I/O interface of MCU 15 and is used to input data to MCU 15.

Referring now to Fig4A, it shows a kind of measuring platform configuration of



measuring apparatus based upon the measuring mode shown in Fig1B. The platform 4 is positioned on scale sensor, and on the platform 4, there are two electrodes 8, 9 with enough area to be contacted by human's sole. Also on the platform 4 there are at least one or more capacitance grid sensors 10, 11 which can be contacted by human's soles and are used to measure dielectric constant of the body endemie-tissues under the skin. Infrared ray transmitting window 5 is positioned on measuring platform 4.

Referring now to Fig4B, it shows another kind of measuring platform configuration of measuring apparatus based upon the measuring mode shown in Fig1B. The platform 401 is positioned on scale sensor, and on the platform 401, there are two groups of electrode 12, 13 comprising electrode plates connected by conducting wires and with enough area to be contacted by human's soles. Also on the platform 401 there are at least one or more capacitance grid sensors 10, 11 which can be contacted by human's soles and are used to measure dielectric constant of the body endemie-tissues under the skin. Infrared ray transmitting window 5 is positioned on measuring platform 401.

Referring now to Fig5A, it shows the system configuration of measuring apparatus shown in Fig4A. Electrodes 8, 9 and capacitance grid sensor 10, 11 are connected with the interfaces of positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endemie-tissues under the skin and body impedance, and positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endemie-tissues under the skin and body impedance is connected with two interfaces of microprocessor MCU system 20 of measuring apparatus. One of the two interfaces is a signal collection interface of MCU system 20 of measuring apparatus, the other is a control interface of MCU system 20 of measuring apparatus used to send switch instruction to positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endemie-tissues under the skin and body impedance in order to switch undetermined multiple frequencies and measuring signal of dielectric constant of body endemie-tissues under the skin. The signal wires of weighing sensor 19 are connected with weighing signal process circuit 18, in which the signal from weighing sensor 19 is converted into frequency signal, and the processed frequency signal is applied to one interface of MCU system 20 of the measuring apparatus through weighing signal processing circuit 18. The determined data by measurement are emitted or received by infrared ray-emitting- receiving circuit 21.

Referring to Fig5B, it shows the system configuration of measuring apparatus shown in Fig4B. Two groups of electrodes 12, 13, which are composed of electrode plates connected with one another by wires and can be in contact with human's soles, and capacitance grid sensors 10, 11 are connected with the interfaces of positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endemie-tissues under the skin and body impedance, and positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endemie-tissues under the skin and body impedance is connected with two interfaces of MCU 20 system of the measuring apparatus. One of the interfaces is the signal collection interface of MCU 20 system of the measuring apparatus and the other is a control interface of MCU system 20 of the measuring apparatus used to send switch instruction to positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endemie-tissues under the skin and body impedance in order to switch undetermined multiple frequencies and the measuring signal of dielectric constant of body endemie-tissues under the skin. The signal wires of weighing sensor 19 are connected with weighing signal process circuit 18, in which the signal from

weighing sensor 19 is converted into frequency signal and the processed frequency signal is applied to one interface of MCU system 20 of the measuring apparatus through weighing signal processing circuit 18. The determined data by measurement are emitted or received by infrared ray-emitting- receiving circuit 21.

Referring now to Fig6, it shows the surface configuration of display apparatus based upon the measuring mode shown in Fig1B. On the process panel of display apparatus 6 are keyboard 2, display 3 and infrared ray transmitting window 22.

In the present invention, there are four embodiment examples of capacitance grid sensor for measuring the dielectric constant of body endermie-tissues under the skin.

Referring now to Fig7A, ~~the capacitance grid sensor for measuring the dielectric constant of body endermie tissues is composed of two non-intersectant electrodes 23.~~

Referring now to Fig7B, ~~the two groups of electrodes 24 of the capacitance grid sensor for measuring the dielectric constant of body endermie tissues are dentiform, nested and non-intersectant.~~

Referring now to Fig7C, ~~the two groups of electrodes 25 of the capacitance grid sensor for measuring the dielectric constant of body endermie-tissues under the skin~~ are equidistant, and circle outward from the circular or rectangular center, and the two groups of electrodes are never intersectant.

Referring now to Fig7D, ~~the electrodes 26 of capacitance grid sensor for for measuring the dielectric constant of body endermie-tissues under the skin~~ are equidistant and non-touching plates, and are connected by conductors to become two equidistant and non-touching electrode groups.

Referring now to Fig8, it shows a measuring method, wherein the subject is connected to the circuit as an impedance element  $R_m$  for measuring body impedance and dielectric constant of body endermie-tissues under the skin. The testee's two feet contact two (groups of) electrode plates 27 simultaneously and respectively. Then the human body is connected as a two end impedance element  $R_m$  with positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance, and a loop is formed at and below the human body waist ~~region~~place. The oscillating frequency of the oscillator circuit is related to the impedance element  $R_m$ . By changing parameters of other elements of oscillator circuit, several different frequency signals are obtained related to body impedances, then the body impedances corresponding to several different frequencies are determined. When the testee's foot soles contact two capacitance grid sensors 28, capacitor  $C_m$  is formed, and the positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance connected with  $C_m$  generates oscillating frequency signals related to dielectric constant of body endermie-tissues under the skin, then this kind of frequency digital signals are dealt with by sampling and the dielectric constant of body endermie-tissues under the skin is determined.

Referring now to Fig9, it shows the system configuration of circuit for measuring dielectric constant of body endermie-tissues under the skin and body impedance by using undetermined frequencies. Human body impedance  $R_m$  is coupled to the positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance, capacitor  $C_m$  formed by capacitance grid sensor together with capacitors  $C_1, C_2, \dots, C_n$ , which are different in values, are introduced to switch circuit 30. Switch circuit 30 is introduced to the positive feedback RC oscillator circuit 14 for measuring the dielectric constant of body endermie-tissues under the skin and body impedance. By switching  $C_1, C_2, \dots, C_n$  in circuit 30 to the positive feedback RC oscillator circuit 14 for measuring

the dielectric constant of body ~~endemie~~-tissues under the skin and body impedance, oscillating signals of multiple undetermined frequencies related to  $R_m$  are generated, then body impedances can be measured corresponding to different frequencies. By switching circuit **30**  $C_m$  is introduced to the positive feedback RC oscillator circuit **14** for measuring the dielectric constant of body ~~endemie~~-tissues under the skin and body impedance and dielectric constant of body ~~endemie~~-tissues under the skin can be measured. The principle is described as follows:

When  $C_1$  is introduced to the positive feedback RC oscillator circuit **14** for measuring the dielectric constant of body ~~endemie~~-tissues under the skin and body impedance, the output frequency of oscillating signal is :

$$f_1 = \frac{K}{R_m C_1}$$

When  $C_1$  and  $C_m$  are in parallel connection and introduced to the positive feedback RC oscillator circuit **14** for measuring the dielectric constant of body ~~endemie~~-tissues under the skin and body impedance, the output frequency of oscillating signal is

$$f_2 = \frac{K}{R_m (C_1 + C_m)}$$

Then can get

$$C_m = \frac{C_1 (f_1 - f_2)}{f_2}$$

While dielectric constant of body ~~endemie~~-tissue under the skin,  $\epsilon_r$  can be gotten by following equation

$$\epsilon_r = \frac{C_m \delta}{\epsilon_0 A}$$

where  $\delta$  is the electrode distance of capacitance grid sensor,  $\epsilon_0$  is vacuum dielectric constant;  $A$  is electrode area forming the capacitance of capacitance grid.

Referring now to Fig10, it is a schematic view showing the circuit for measuring the dielectric constant of body ~~endemie~~-tissues under the skin in the positive feedback RC oscillator circuit for measuring dielectric constant of body ~~endemie~~-tissues under the skin and body impedance. The circuit is made up of two invertors, capacitor  $C_a$ , resistor  $R_a$ , body impedance  $R_m$  and capacitance grid sensor  $C_m$  in contact with human's soles. The connection between capacitance grid sensor  $C_m$  and capacitor  $C_a$  is in series, and the other ends of the series circuit are respectively connected with the output end of one invertor and input end of the other invertor. The connection between  $R_a$  and  $R_m$  is in series, and the other ends of the series circuit are respectively connected with the input end and the output end of one invertor. The input end of one invertor is connected with the output end of the other invertor.

Referring now to Fig11, it is a schematic view showing the circuit for measuring the body impedance in the positive feedback RC oscillator circuit for measuring dielectric constant of body ~~endemie~~-tissues under the skin and body impedance. The circuit comprises two invertors, resistor  $R_a$ , capacitor  $C_a$  and body impedance  $R_m$ . The capacitance grid sensor  $C_m$  is a short-circuit capacitance in the circuit. The input end of one invertor is connected with the output end of the other invertor, between the joint of the two invertors and the input end of the invertor, the series-wound circuit comprised by resistor  $R_a$  and body impedance  $R_m$  is introduced. The two ends of the

capacitor Ca are connected respectively with the two invertors' two ends that are not connected with each other. The oscillating frequency of the oscillator circuit can change with the different body impedance Rm.

Referring now to Fig12, it is a schematic view showing another kind of circuit for measuring the body impedance in the positive feedback RC oscillator circuit for measuring dielectric constant of body endemie-tissues under the skin and body impedance. The circuit comprises one D trigger, resistors Ra1 and Ra2, capacitor Ca1 and body impedance Rm. The body impedance Rm is in series connection with resistor Ra1 and then in parallel connection with resistor Ra2. The one end of the circuit in series-parallel connection is connected with the invert end of the D trigger, and another end is connected with the CD end, CLK end, and GND end of the D trigger. The oscillating frequency of the oscillator circuit can change with the different body impedance Rm.

Referring now to Fig13, it shows the circuit system based upon the display apparatus shown in Fig6. Keyboard 34, display 35 and infrared emitting-receiving circuit 32 are all connected with corresponding interfaces of MCU system 31 of the display apparatus.

Referring now to Fig14, it shows the configuration of infrared signal transmitting circuit configuration of measuring apparatus based upon the measuring mode shown in Fig1B. Electrical signal is input from the base electrode of audion T1, the collectors of audion T1 and T2 are connected with one port of infrared emitter 36, and the other port of infrared emitter 36 is connected with current-limiting resistor R1, infrared emitter 36 emits infrared data signal 7. Infrared receiver 38 receives the infrared instruction signal emitted by display apparatus when operated, and converts the infrared signal to electrical signal, which is then transmitted from infrared receiver 38 to the base electrode of audion T3. The collector of audion T3 is connected with the input level of decoder 37. The output level of decoder 37 is connected with MCU system 20 of the measuring apparatus. This circuit makes measuring apparatus realize the two-direction transition of infrared signal.

Referring now to Fig15, it shows the configuration of infrared signal transmitting circuit in display apparatus. Infrared receiver receives the data signal emitted from measuring apparatus, and the data signal is converted to electrical signal, which is then transmitted from infrared receiver 29 to the base electrode of audion T7. The collector of audion T7 is connected with the interface of MCU system 31 of the display apparatus. The interface of MCU system 31 of the display apparatus sends electrical signal to the input interface of encoder 39, whose output interface is connected with the base electrode of audion T5. The collectors of audion T5 and T6 are connected with one port of infrared emitter 33, and the other port of infrared emitter 33 is connected with current-limiting resistor R4. Infrared emitter 33 emits infrared instruction signal 7. This circuit makes display apparatus realize the two-direction transition of infrared signal.

The advantages of the present invention are: 1. To jointly evaluate body composition by using the two measuring parameters of body impedance by measurement and the dielectric constant of body endemie-tissues under the skin measured by the capacitance grid sensor in contact with the human body's skin, so to decrease the uncertainty caused by assessment using only one measured parameter; 2. To measure the body impedance and dielectric constant of body endemie-tissues under the skin based on the method of frequency digital sampling, so to leave out the A/D converting part and to improve the measuring accuracy; 3. To measure body impedance by using non-fixed multiple frequency method, so to make the body

difference to be indicated more obviously in body impedance difference and to indicate the body composition status genuinely. The apparatus of the present invention is used to conveniently monitor the body composition in everyday life.

## ~~Abatrast~~ABSTRACT

A method for measuring dielectric constant of body endermic tissues and body impedance based on the method of frequency digital sampling and for evaluating body composition, inputting through the I/O interface of a microprocessor he measured bogy weight frequency signals, oscillating frequency signals related to dielectric constant of body endermic tissues and body impedance signals corresponding to non-fixed different frequencies, calculating through the software of the microprocessor the body fat content, total body water, ratio between intracellular water and total body water and displaying the body weight, body fat content ,total body water and ratio between intracellular water and total body water on the display;

A body composition monitor based on above method unit, which comprises weighing sensor and weighing signal processing circuit, and display unit.